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Retrospective clinical study of single-retainer anterior and posterior glass-ceramic resin-bonded fixed dental prostheses at a mean follow-up of 5 years

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Abstract:

Aim: To retrospectively evaluate the 5-year survival rates and technical and biological complication rates of *single-retainer all-ceramic resin-bonded fixed dental prostheses* (RBFDPs).

Materials & Methods: 40 patients (24 female, 16 male) treated with 49 anterior and posterior glass-ceramic RBFDPs (Empress, e.max Press, Ivoclar Vivadent AG, Schaan, Liechtenstein) were included in this study. The RBFDPs replaced 11 missing maxillary or mandibular central incisors, 18 lateral incisors, 18 premolars and 2 molars. The patients willing to participate were clinically and radiologically examined. The RBFDPs were examined for their technical outcomes by means of modified United States Public Health Service (USPHS) criteria. Parameters assessed were fracture and/or chipping of the restoration, occlusal wear, marginal adaptation, marginal discoloration, shape and contour, surface texture and esthetic color integration. Furthermore, tooth vitality and postoperative sensitivity were recorded. The following biologic parameters were assessed at test (abutment) and control (analogous contra-lateral untreated) teeth: probing pocket depth (PPD), gingival recession (MG), attachment loss (AL), bleeding on probing (BOP), furcation involvement and periodontal mobility. Statistical analysis was performed with exact 95% confidence intervals to relative frequencies (Documenta Geigy, 1980) and the paired t-test ($p<0.05$).

Results: Twenty-eight patients with 35 RBFDPs participated in the study. The mean follow-up period of the RBFDPs was 5.7 years (min: 0.31, max: 13.5). Twelve patients with 14 RBFDPs were not willing to participate or were not available. No catastrophic failures of the RBFDPs were found. The 5-year survival rate of the examined RBFDPs was 100% [95% CI

(90%, 100%)]. No debonding was recorded. Chipping of the ceramic was found in 5.7% [95% CI (0.70%, 19.16%)] of the RBFDPs. No differences of the biologic outcomes at test and control teeth were found (test: mean (m)PPD 2.4, mMG -0.6, mAL 2.5, mBOP 0.20; control: mPPD 2.3, mMG -0.6, mAL 2.4, mBOP 0.24).

Conclusion: Glass-ceramic RBFDPs exhibited very promising clinical outcomes both in anterior and posterior regions. Prospective randomized controlled studies are needed to elucidate the present observations.

Introduction:

The approach to replace single missing maxillary or mandibular teeth with *resin-bonded fixed dental prostheses* (RBFDPs) dates back to the 1970s (1, 2). The main indications of the RBFDPs were splinting of periodontally compromised anterior teeth or replacement of missing teeth (1, 2). RBFDPs have several advantages over other treatment options for the replacement of teeth. The main advantage of RBFDPs is the low invasiveness compared to conventional FDPs, as no or only little abutment tooth preparation is needed. In a recent laboratory study Edelhoff et al. showed, that 25% to 50% less tooth substance is removed for a RBFDPs as compared to a conventional complete-coverage metal-ceramic reconstruction (3, 4). Furthermore, this treatment option caused less patient morbidity. By means of RBFDPs surgical interventions for the replacement of single teeth like single tooth implants could be avoided. Finally, the treatment costs associated with RBFDPs are considerably lower than for conventional FDPs or single-tooth implants (5).

As reported in the literature the main problem associated with RBFDPs was de-bonding. In a systematic review Pjetursson et al. (6) RBFDPs showed a 19.2% cumulative rate of de-bonding during 5-years of observation. The de-bonding most frequently occurred at metal-ceramic RBFDPs fabricated with perforated cast metal frameworks (6). The use of non-perforated cast metal frameworks improved the poor performance of the RBFDP (6). Still, the adhesive cementation of the metal-ceramic RBFDPs remained to be a challenge.

After the advancement of ceramic materials, first *all- ceramic* RBFDPs were made in the early 1990s (7). One of the benefits of ceramics is that the adhesive cementation of this material is well established and predictable (8). The first ceramic RBFDPs exhibited very promising clinical survival rates of 92.3% at 5 years (9). De-bonding was a seldom complication at the all-ceramic FDPs (9). Yet, due to their brittleness all-ceramic RBFDPs exhibited a high risk for fracture compared to the conventional metal-ceramic RBFPDs (9). It

has been shown, that the clinical stability could be improved by changing the design of the reconstructions from 2-retainer to single-retainer cantilever RBFDPs (9). A clinical study showed, that all-ceramic anterior RBFDPs exhibited significantly better survival rates when they were designed as cantilever RBFDPs (9). Nevertheless, due to the specific material properties of ceramics the all-ceramic RBFPDs might only be appropriate for the replacement of missing anterior teeth.

Up to date very little information is available on the outcomes of anterior all-ceramic RBFDPs, and no data is available on posterior all-ceramic RBFDPs.

Therefore, the purpose of this retrospective clinical study was to assess the 5-year survival rates and technical and biological complication rates of *single-retainer cantilever all-ceramic resin-bonded fixed dental prostheses* (RBFDPs), replacing single anterior and posterior teeth.

Materials and Methods

Patients and Reconstructions

The patients included in this study were part of a group of 40 patients (24 female, 16 male) treated with at least one all-ceramic RBFDP in the anterior or posterior region of the maxilla or mandible. The all-ceramic RBFDPs were made out of one of 2 glass-ceramics (Empress, e.max Press, Ivoclar Vivadent AG, Schaan, Liechtenstein).

All patients were treated in one private practice in the years 1994 to 2006. The age of the patients ranged between 10 and 61 years.

The criteria for the decision, whether or not the patients/sites were indicated for the RBFDPs, were:

- single tooth gap in anterior (incisor) and/or posterior (premolar, molar) regions
- patient's desire for minimally invasive treatment
- patient's desire for all-ceramic tooth-borne reconstruction
- periodontally healthy neighboring teeth
- inter-occlusal space adequate for the retainer in horizontal and vertical dimensions
- presence of an abutment tooth distally of the gap in posterior regions
- no obvious signs for bruxism

Prior to the fabrication of the RBFDPs the suitable patients were thoroughly informed about the clinical procedures, the advantages and limitations of the all-ceramic RBFDPs, and the present insufficiency of scientific evidence. Furthermore, treatment alternatives (conventional FDPs, single tooth implants) were discussed with the patients.

The 40 patients interested in the RBFDPs provided informed consent for this treatment option, and were treated with 49 *cantilever single-retainer all-ceramic resin-bonded fixed*

dental prostheses (RBFDPs). The RBFDPs replaced central incisors, lateral incisors, premolars (Fig 1) and two molars.

Prosthodontic Procedures

All patients were subjected to dental hygienic pre-treatment prior to the restorative treatment phase. In the anterior region the choice of the abutment tooth was made after judging the amount of space in horizontal and vertical dimensions during centric occlusion and function. No preparation of the anterior abutment teeth was perfomed. In the posterior region, the tooth distal to gap was chosen as abutment tooth. Minimal inlay tooth preparation was perfomed following the shape and size of pre-existing cavities. Impressions were made with a polyether impression material (Permadyne, 3M ESPE, Germany). No provisional reconstruction was needed in the anterior region, in the posterior regions the cavities were filled with a provisional composite (Fermit, Ivoclar Vivadent AG, Schaan, Liechtenstein).

The impressions were poured with Class IV stone (GC FUJIROCK EP, golden brown, Leuven, Belgium) in the dental laboratory and full anatomic wax-models (S-U-ÄSTHETIKWACHSE - O, apricot & beige, Schuler Dental, Ulm, Germany) of the desired RBFDP were manually made. The wax models were embedded (IPS PressVest, IPS PressVest Speed, Ivoclar Vivadent AG, Schaan, Liechtenstein). Finally, the RBFDP were pressed out of one of the 2 glass-ceramics using the lost-wax technique. The framework dimensions were adjusted to the manufacturer's recommendations for the glass-ceramics. The minimal dimensions of the connector for framework retainers were 16 mm^2 for the anterior region and 20 mm^2 for the posterior region. In anterior regions the RBFDPs were veneered (IPS e.max Ceram for e.max - Empress Esthetic Veneer Materials for Empress, Ivoclar Vivadent AG, Schaan, Liechtenstein), in posterior regions the RBFDP were adjusted to the color of the neighboring teeth with the corresponding ceramic colors (IPS Empress Universal Shades and Stains, Ivoclar Vivadent AG, Schaan, Liechtenstein).

Forty-six RBFDPs (93.9%) were made of a lithium disilicate re-inforced glass-ceramic (*IPS e.max Press, Ivoclar Vivadent AG, Schaan, Liechtenstein*) and 3 (6.1%) of a leucite re-inforced glass-*ceramic (IPS Empress, Ivoclar Vivadent AG, Schaan, Lichtenstein)*. All FDPs were adhesively bonded to the abutment teeth using one of the following resin cements: Tetric Flow (*Ivoclar Vivadent AG, Schaan, Lichtenstein)* was used as luting agent for 33 (67.3%) restorations, Tetric Ceram (*Ivoclar Vivadent AG, Schaan, Lichtenstein)* for 7 (14.3%), Rely-X *(3M ESPE, Neuss, Germany)* for 4 (8.2%), Panavia F *(KURARAY dental, New York, United States)* for 3 (6.1%), HFO *(Optident, West Yorkshire, United Kingdom)* for 1 (2.0%), and Variolink (*Ivoclar Vivadent AG, Schaan, Lichtenstein)* for 1 (2.0%). Prior to cementation, the abutment teeth were acid etched (Total Etch, 37% phosphoric acid, *Ivoclar Vivadent AG, Schaan, Lichtenstein*) and subsequently pre-treated with the bonding agents (Syntac, *Ivoclar Vivadent AG, Schaan, Lichtenstein*) corresponding to the respective cements according to manufacturers' instructions (10, 11).

Clinical follow-up Examination

The RBFDPs were examined for technical and biologic outcomes (failures or complications). The technical outcome of the reconstructions was examined using modified United States Public Health Services (USPHS) criteria (Table 1) (12). An outcome was rated *A* when no problems were found, *B* when small but clinically acceptable defects were found, *C* when the defects reached a level that was no longer clinically acceptable and *D* when the RBFDP had to be replaced due to the defect (Table 1). The biologic outcome was analyzed at test (abutment) and control teeth (analogous, contra-lateral, not crowned) by determining: probing pocket depth (PPD), gingival recession (MG), attachment loss (AL), bleeding on probing (BOP), furcation involvement (Index according to Rateitschak et al.) (13), and periodontal mobility (Index according to *Flemming* et al.) (14). Finally, radiographs and clinical photographs of the abutment teeth were taken. One investigating dentist performed all follow-up examinations

using magnification loupes with a 2.5 x magnification (TP 710, SandyGrendel, SwissLoups, Switzerland) (15).

Statistical Analysis

Descriptive statistics were applied to the data. The 5-year survival rate of RBFDPs was computed by dividing the number of RBFDPs without any fractures by the total number of clinically examined RBFDPs. Failure and complication rates were calculated by dividing the number of observed events (failures or complications) by the total number of analyzed RBFDPs. The exact 95% confidence intervals (95% CI) for relative frequencies were obtained from the Documenta Geigy (Wissenschaftliche Tabellen Geigy, Teilband Statistik, 8. Auflage, 1980). For the comparison of PPD, MG, AL and BOP between test and control teeth the paired t-test was used. The data were analyzed by SPSS Version 17.0. The level of statistical significance was set at alpha= 0.05.

Results:

Twenty-eight patients with 35 RBFDPs were examined. The mean clinical service time of the RBFDPs was 5.7 years (min: 0.31y, max: 13.5y). Twelve patients with 14 RBFDPs did not participate in the follow-up examination out of different reasons. One patient had passed away, one had emigrated, and 8 did not wish to participate. Furthermore, in one patient the RBFDP had been removed and replaced by a dental implant. The patient reported, that this treatment was performed on his wish and that the RBFDP had no complications before the removal. In another patient one RBFDP was lost, because the abutment tooth had to be extracted out of periodontal reasons.

No catastrophic fracture of a clinically examined all-ceramic RBFDP occurred. Furthermore, none of the RBFDPs had to be removed due to technical or biological complications [95% CI (0.00%, 10.00%)]. The examined RBFDP, therefore, had a 5-year survival rate of 100% [95% CI (90%, 100%)].

Technical outcomes

No de-bonding of a RBFDP was found. Minor technical complications encompassed chipping of the ceramic, which was found at 2 RBFDPs. The rate for chipping of the ceramic, therefore, was 5.7% [95% CI (0.70%, 19.2%)]. In both cases the rough surfaces were meticulously polished.

Minor occlusal wear of the ceramic (USPHS rating B) was found in 74.3% [95% CI (59.9%, 89.6%)] of the reconstructions. Occlusal wear rated C was found in 5.7% [95% CI (0.7%, 19.2%)].

Most of the reconstructions showed a fair marginal adaptation with slightly visible but polishable marginal discoloration. Clinically acceptable marginal gaps (USPHS rating B) were found at 68.6% [95% CI (50.7%, 83.2%)] of the RBFDPs. In 2.9% [95% CI (0.1%, 14.9%)] of the RBFDPs the margins were discolored (Fig 2).

The proximal contacts were tight and in case of minimal deviation from the ideal occlusion and articulation a correction was achieved by grinding. A slightly rough surface with a minimal mismatch in shade was also often found.

The detailed information on the technical outcomes (USPHS criteria) of the RBFDPs is given in Table 2.

Biological outcomes:

In general, no differences of the biological outcomes were found when test and control teeth were compared. All abutment teeth showed a distinct positive feedback on the tooth vitality. No restrictions in postoperative sensitivity were recorded. Detailed information on the biologic outcomes of the reviewed RBFDPs is given in Table 3.

The mean PPD (mPPD) of the abutment teeth was 2.4 mm (min: 1.33, max: 3.88), the mPPD of the control teeth was 2.3 mm (min: 1.5, max: 3.83). Mean gingival recession of 0.6 mm was found both at the abutment and control teeth. A mean loss of attachment (mAL) of 2.5 mm (min: 1.25, max: 4.25) was found at the abutment teeth. The respective mAL of the control teeth was 2.4 mm (min: 1.25, max: 3.88). Finally, the same amount of mBOP was found at the test and control teeth.

No posterior abutment tooth exhibited a furcation involvement bigger than grade I (not more than 3 mm in horizontal direction, according to Rateitschak et al.) (13). No abutment tooth mobility exceeding grade I was found at the test teeth (according to *Flemming* et al.) (14).

Discussion

The anterior and posterior glass-ceramic cantilever RBFDPs exhibited very good survival rates and low complication rates in the present retrospective study. Only minor technical complications like polishable chipping of the ceramic or marginal discoloration were found. Furthermore, the RBFDPs also exhibited excellent biological integration. No difference of the biological outcomes of the abutment teeth were found as compared to untreated control teeth.

Different survival rates of RBFDPs have been reported in the literature, indicating that the outcome of this kind of reconstruction is influenced by many clinical and technical factors. One study showed an overall success rate of 94% after a mean observation time of 36.2 months (16). Another study showed a 100% survival rate of cantilever RBFDPs after a mean observation time of 35 months (17). In a systematic review of the literature overall estimated a rather low survival rate of RBFDPs with 87.7%, though (6). The review indicated, furthermore, that the survival rates of the anterior RBFDPs were exceeding the ones of the posterior RBFDPs. However, this review predominantly included literature on metal-ceramic RBFDPs (6).

Studies reporting on all-ceramic RBFDPs in anterior and/ or posterior regions are scarce. One long-term study on anterior ceramic cantilever RBFDPs reported a 10-year survival rate of 94.4%. The same study also showed that the ceramic RBFDPs exhibited lower survival rates when they were cemented to two adjacent abutment teeth (two-retainer design) (18). The survival rates of the all-ceramic cantilever RBFDPs in the present study were very promising both in anterior and posterior regions. It has to be considered, though, that this study was retrospective. Only a part of the initially treated patients were clinically examined, which limits the interpretation of the results. Randomized controlled clinical studies are, therefore, needed to further analyze the present observations of the all-ceramic cantilever RBFDPs.

A number of studies showed that the longevity of RBFDPs was influenced by clinical and technical factors like e.g. the design of the abutment tooth preparation, the type of cement

used for the fixation and the surface pre-treatment of the tooth and reconstruction (19, 20). In addition, the type of material for the RBFDP, e.g. the type of casting alloy or ceramic, seems to be an important factor (19).

The technical outcomes found in the present retrospective study are in accordance to the results of other studies. Catastrophic fracture of a ceramic RBFDP did not occur in the present study. In another study on ceramic RBFDP, the number of fractures of the all-ceramic RBFDPs also was rather low (21). One further study reported a 7.7% fracture rate of the RBFDPs (9). De-bonding was the main technical complication occurring in the studies on RBFDPs (6), this complication did not occur in the present study. Furthermore, the rates for chipping of the veneering ceramic and marginal deficiency were low in the present study.

Hence, in case of single-tooth gaps in the anterior and possibly also in the posterior region the question whether an implant or a RBFDP is indicated should be further elucidated. A RBFDP may be a valid alternative in situations where an implant treatment is not medically indicated. Absolute contraindications for implantations are e.g. immune-suppression, active treatment of malignancy, drug abuse or psychiatric illness (22). Furthermore, various "relative" contraindications like diabetes or cardiovascular diseases were reported (23). Finally in case of lack of space for an implant, an all-ceramic RBFDP may be a good alternative. One example is a crowded mandibular anterior dentition. Another indication for RBFDPs are young patients with congenitally missing teeth and not completed facial growth. In that case, the RBFDP may be an acceptable temporary solution. After completed facial growth, the cantilever can be easily removed and replaced by an implant if desired. A recently presented study showed that single-implant restorations in the anterior maxilla may present small degrees of infraposition in long-term perspectives (24).

The main challenge in carrying out long-term studies is the compliance of the patients to participate in follow-up examinations. In the present retrospective study the 70% of the initially treated patients participated. Therefore, conclusions have to be drawn with caution.

Until today the all-ceramic RBFDPs are judged as semi-final reconstructions, since very few studies reporting their outcomes are available. In order to further elucidate their indications and limitations, and the long-term outcomes of the RBFDPs randomized controlled clinical studies are needed in the future.

Conclusion:

The anterior and posterior all-ceramic RBFDPs in the present study exhibited very promising clinical outcomes at 5-years of follow-up. This treatment means, therefore, might be a good alternative to single-implant crowns in the future. In order to test this assumption, future studies using a prospective controlled design are needed.

Figures and Tables:

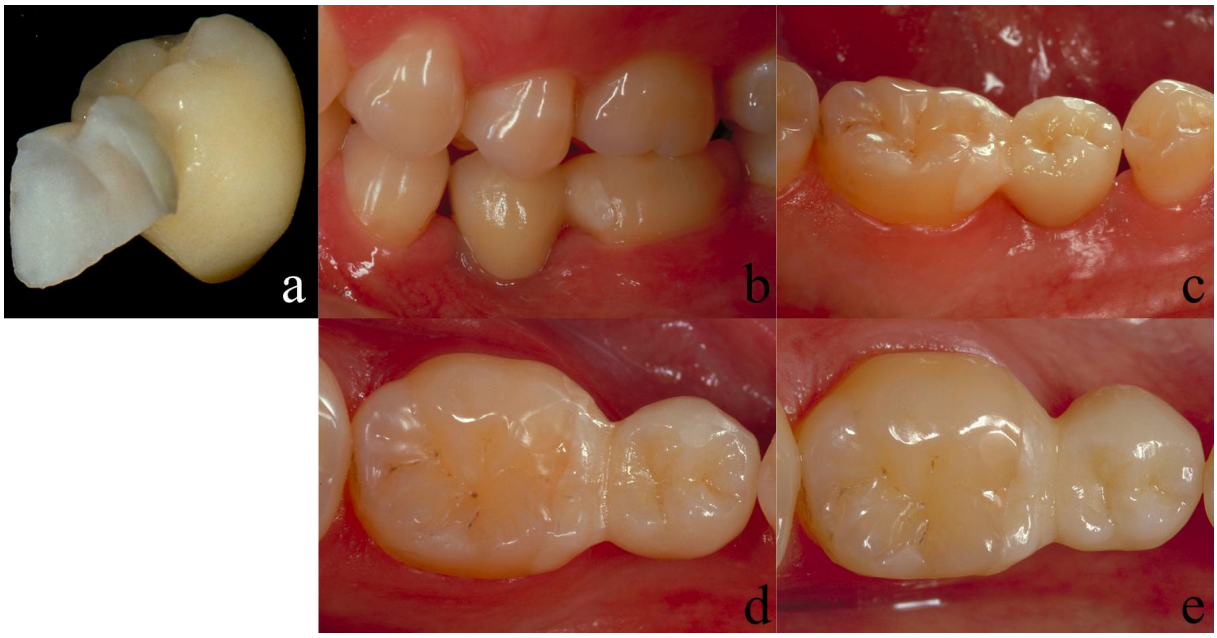

Fig 1a to 1e

a Distobuccal view of the all-ceramic RBFDP replacing tooth 35. Vestibular **b**, lingual **c** and occlusal **d** view of the inserted RBFDP. **e** Identical RBFDP after follow-up period of 6 years.

Fig 2 Lingual view of two all-ceramic RBFDPs replacing tooth 31 and tooth 41. Distinct marginal discoloration visible at the abutment tooth 42. The follow-up period of the RBFDPs was 6.9 years.

Table 1 USPHS criteria

	Alpha (A)	Bravo (B)	Charlie (C)	Delta (D)
Fracture:	No fracture of the restoration			Fracture of the restoration
Chipping of ceramic:	No chipping	Chipping, but polishing possible	Chipping, no polishing possible	New reconstruction is needed
Quality of marginal gap:	Probe did not catch	Probe did catch, no gap, exposed enamel is polishable	Probe did catch, with gap, exposed cement is not polishable	New reconstruction is needed
Marginal adaptation:	No cement joint	Cement joint >50 micrometer *without* degradation	Cement joint >50 micrometer *with* degradation	New reconstruction is needed
Marginal discoloration:	No marginal discoloration	Slight discoloration visible, but polishable	Distinct discoloration visible, not polishable	New reconstruction is needed
The configuration of the contour:	Correct contour, tight proximal contacts	Slightly under- or over-contoured, weak proximal contacts	Distinct under- or over-contoured, no proximal contacts	New reconstruction is needed
Occlusion:	Perfect occlusion and articulation	Minimal deviation in occlusion and articulation, correction achieved by grinding	Distinct deviation in occlusion and articulation, transversal and sagittal slide > 1mm	New reconstruction is needed
Occlusal wear:	No wear facets on restoration and opposing teeth	Small wear facets (diameter <2mm) on restoration and/or opposing teeth	Large wear facets (diameter >2 mm) on restoration and/or opposing teeth	New reconstruction is needed
Surface texture:	Smooth, glazed or glossy surface	Slightly rough, dull surface, polishable	Deep pores, rough, unevenly distributed pits, not polishable	New reconstruction is needed
Color:	Perfect match of color	Minimal mismatch in shade	Distinct difference in shade	New reconstruction is needed
Assessment of tooth vitality:	Distinct positive feedback on the tooth vitality or a negative feedback by endodontically treated teeth	Delayed reaction	Negative feedback by not endodontically treated teeth	New reconstruction is needed
Postoperative sensitivity:	No restrictions in postoperative sensitivity	Minimal restrictions in postoperative sensitivity	Distinct restrictions in postoperative sensitivity, the patient wants a new reconstruction	New reconstruction is needed

Table 2 USPHS rating of RBFDPs in percentage

n = 35	Alpha (A)	Bravo (B)	Charlie (C)	Delta (D)
Fracture:	100 (90.0, 100.0)	*	*	*
Chipping of ceramic:	94.3 (80.4, 99.3)	5.7 (0.7, 19.2)	*	*
Quality of marginal gap:	31.4 (16.9, 49.3)	68.6 (50.7, 83,2)	*	*
Marginal adaptation:	20 (8.4, 36.9)	77.1 (59.9, 89.6)	2.9 (0.1, 14.9)	*
Marginal discoloration:	8.6 (1.8, 23.1)	88.6 (73.3, 96.8)	2.9 (0.1, 14.9)	*
The configuration of the contour:	85.7 (69.7, 95.2)	14.3 (4.8, 30.3)	*	*
Occlusion:	57.1 (39.4, 73.7)	42.9 (26.3, 60.7)	*	*
Occlusal wear:	20 (8.4, 36.9)	74.3 (56.7, 87.5)	5.7 (0.7, 19.2)	*
Surface texture:	20 (8.4, 36.9)	80 (63.1, 91.6)	*	*
Color:	25.7 (12.5, 43.3)	68.6 (50.7, 83,2)	5.7 (0.7, 19.2)	*
Assessment of tooth vitality:	91.4 (76.9, 98.2)	8.6 (1.8, 23.1)	*	*
Postoperative sensitivity:	100 (90.0, 100.0)	*	*	*

*** = 0% (0.0, 10.0)****

**** = percentage of events (95% CI for the true relative frequencies)**

Table 3 Biologic outcome rating of RBFDPs

n = 35	abutment tooth		reference tooth		
	mean +/- SD	95% CI (mean)	mean +/- SD	95% CI (mean)	p
PPD	2.4 +/- 0.5	(2.2, 2.5)	2.3 +/- 0.5	(2.1, 2.4)	0.455
MG	-0.6 +/- 0.6	(-0.8, -0.4)	-0.6 +/- 0.6	(-0.8, -0.3)	0.705
AL	2.5 +/- 0.9	(2.2, 2.8)	2.4 +/- 0.8	(2.1, 2.7)	0.288
BOP	0.2 +/- 0.2	(0.13, 0.26)	0.2 +/- 0.2	(0.17, 0.31)	0.259

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